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Research Article

The Impact of Learning Multiple Real-World Skills on Cognitive Abilities and Functional Independence in Healthy Older Adults

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Abstract

Objectives: The natural learning experience from infancy to emerging adulthood, when considerable cognitive and functional growth is observed, mandates learning multiple real-world skills simultaneously. The present studies investigated whether learning multiple real-world skills simultaneously is possible in older adults and also whether it improves both their cognitive abilities (working memory, episodic memory, and cognitive control) and functional independence.

Methods: Over two studies (15 and 27 participants), older adults learned at least three new skills (e.g., Spanish, drawing, music composition) simultaneously for 3 months. Participants completed cognitive and functional assessments before, during, and after the intervention in both studies. Participants were recruited sequentially for an intervention or no-contact control group in Study 1, and Study 2 included only an intervention group, who also completed assessments 4–6 weeks prior to the start of the intervention (i.e., they served as their own control group).

Results: Results from both studies show that simultaneously learning multiple skills is feasible and potentially beneficial for healthy older adults. Learning multiple skills simultaneously increased cognitive abilities in older adults by midpoint of the intervention, to levels similar to performance in a separate sample of middle-aged adults.

Discussion: Our findings demonstrate the feasibility and potential of conducting a real-world skill-learning intervention involving learning three novel skills with older adults. Our multiskill intervention may provide broad cognitive gains, akin to the benefits experienced earlier in the life span.

Keywords: Cognitive intervention, Engagement, Skill learning, Adaptation

Optimal/successful aging involves flexibly adapting to novel problems to maximize long-term functional independence and related cognitive abilities in the ever-changing environment (Nguyen, Leanos, Natsuaki, Rebok, & Wu, 2020). To adapt to this dynamic environment, simultaneously learning multiple real-world skills may equip learners with the tools that can be applied broadly to subsequent learning experiences required for long-term cognitive gains and functional independence (Wu, Rebok, & Lin, 2017). However, previous real-world skill-learning interventions have focused mostly on learning a single real-world skill or multiple skills in sequence. Although it is unclear how learning multiple real-world skills simultaneously may affect cognitive and functional abilities in older adulthood, prior single-skill interventions with older adults provide evidence that it is possible to alter unfavorable decline trajectories expected in cognitive aging (see Hertzog, Kramer, Wilson, & Lindenberger, 2008).

Prior real-world skill-learning interventions (i.e., cognitive engagement interventions) with community-dwelling older adults have found that learning one new real-world skill at a time (e.g., photography) can increase cognitive abilities employed by that skill. For example, Park and colleagues (2014) found that older adults who learned one skill (i.e., quilting *or* photography) or both skills *sequentially* with qualified instructors for 3 months increased in episodic memory. During the intervention, photography participants learned how to use a digital camera and photo-editing software, and quilting participants learned how to design and sew quilts with sewing machines that had a digital interface. Park and colleagues proposed that episodic memory increased by

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post-test because it is required for learning how to use software and a digital camera or a computer-driven sewing machine. Similarly, Chan, Haber, Drew, and Park (2016) found that older adults who learned how to use an iPad in a 3-month intervention (e.g., using the iPad for social media, health, and finance) displayed improvements in episodic memory and processing speed, compared with a social interactions group and a no active skill-learning group. In a series of studies, Noice, Noice, and Staines (2004) showed that participating in acting classes (e.g., performing scenes from memory) for 1 month increased performance on tasks related to episodic memory, working memory, and problem solving compared with a waitlist control group. Six months of individual piano lessons (e.g., learning scales and new songs), which require working memory and executive functions, increased performance on digit span and trail making tests, compared with a no-contact control group (Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, 2007). In these prior interventions, cognitive improvements typically were observed only for the abilities that were required for the learned skill. Therefore, perhaps learning multiple skills simultaneously may produce broader benefits in multiple cognitive abilities, akin to broad cognitive growth observed from infancy to young adulthood.

Although skill-learning interventions typically include only one skill at a time, the possible benefits of simultaneously learning multiple skills (i.e., varied learning) are supported by prior studies that did not involve an intervention with older adults. An observational study with older adults found that variability in activity engagement is more beneficial than frequency of activity engagement (Carlson et al., 2012). In general, varied learning allows the learner to encounter diverse learning problems, examples, and solutions, such as speaker variability for language acquisition (e.g., Rost & McMurray, 2009) and practicing different types of motor activities for tracking abilities (e.g., Wulf & Schmidt, 1997). The learner benefits from identifying similarities and differences among learning examples (e.g., relational learning; Gentner, 2005). Variability allows for generalization (transfer, Barnett & Ceci, 2002), linking two concepts or applying a known concept to a novel context. Investigating the effects of learning multiple skills simultaneously also goes beyond prior studies analyzing the benefits of specific skills (e.g., Karp et al., 2006), which may not serve older adults who are not interested or limited in engaging in those skills (e.g., physical exercise; Lachman, Lipsitz, Lubben, Castaneda-Sceppa, & Jette, 2018).

In addition to the learning opportunities themselves, other social and cognitive factors are important to consider in relation to learning. The learning environment for older adults is often characterized by increasingly negative stereotypes (Barber, 2017; Lamont, Swift, & Abrams, 2015; Ng, Allore, Trentalange, Monin, & Levy, 2015), prescriptive age biases (e.g., North & Fiske, 2013), low expectations and negative feedback (e.g., Nguyen et al., 2020; Strickland-Hughes, West, Smith, & Ebner, 2017), maintenance and/or compensation (e.g., Selection, Optimization, and Compensation [SOC] theory; Baltes, Lindenburger, & Staudinger, 2006), and focusing on socioemotional gains rather than cognitive gains (e.g., Socioemotional Selectivity Theory; Carstensen, 1995). Even though older adults have different cognitive and neurological profiles when compared with infants and children, older adults may benefit from aspects of the rich learning environment typical of younger age groups, which includes learning multiple skills simultaneously in an encouraging environment (Cognitive Agility across the Lifespan via Learning and Attention [CALLA] theory; Wu et al., 2017).

The Present Studies

Two studies investigated whether a 3-month cognitive intervention involving simultaneously learning multiple (three or more) real-world skills would increase cognitive abilities and functional independence in older adults. The target outcomes of the intervention were working memory, cognitive control, and episodic memory because these cognitive abilities are among the first to decline with increased age and underlie more complex, higher-order cognitive functions (Park & Reuter-Lorenz, 2009; Salthouse, 2006), as well as being required for daily functional tasks. Study 1 investigated the feasibility of learning multiple skills simultaneously in older adults, as well as potential increases in working memory, cognitive control, episodic memory, and functional independence compared with a no-contact control group. We hypothesized that simultaneously learning multiple new real-world skills would increase both cognitive abilities and functional independence by post-test, even if the learned skills were not directly related to the cognitive and functional independence assessments. Study 2 aimed to replicate the cognitive and functional independence results from Study 1 with a larger sample and wider variety of real-world skills learned.

Study 1

Method

Participants

Six older adults (four females, two males, M_{age} = 66.33 years, SD_{age} = 6.41, range = 58–74 years old) participated in a 15-week intervention (Figure 1). Three additional participants (one female, two males, M_{age} = 82.67 years, SD_{age} = 6.81, range = 75–88) withdrew from the intervention due to spousal health issues or personal cognitive/medical health issues. Two of those participants withdrew before any study activities (but after being matched to control participants), and one withdrew in the third week of the intervention. Therefore, completion rate of the intervention was six of seven participants, or 86%, similar to Park and colleagues (2014; 85%). Nine older adults participated in a no-contact control group (six females, three males, M_{age} = 70.22 years, SD_{age} = 9.97, range = 58–86). These participants were recruited separately 2 weeks after the start of the intervention from the same pool of potential participants. Two of the nine participants dropped out (two females, M_{age} = 73.50 years, SD_{age} = 17.68, range = 61–86) for unknown reasons. Sociodemographic variables for participants from both groups are included in Table 1, and enrollment, adherence, and retention rates are summarized in Figure 1. The screening-to-enrollment ratio for the intervention group was 20%.

Individuals from various sources and locations were contacted to participate in the intervention and control group (Figure 1): these sources and locations included the University of California, Riverside's Participant Pool for Research on Aging recruited from around the Riverside community, a local Osher Lifelong Learning program, and neighborhood message boards. A focus group conducted prior to the intervention included 13 participants (M_{age} = 73.92 years, SD_{age} = 9.81, range = 56–89). All focus group participants were invited to participate in Studies 1 and 2: three participated in Study 1 and two in Study 2.

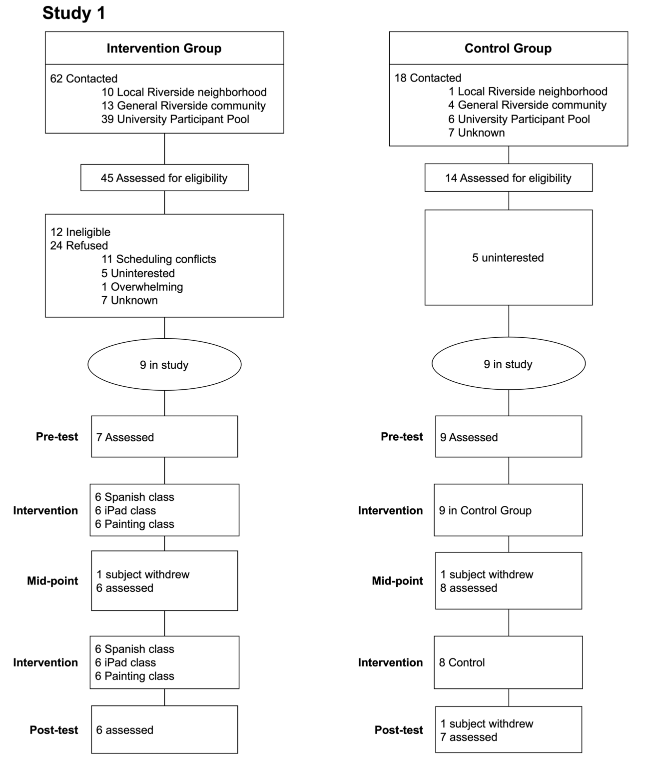

Figure 1. The number of individuals throughout the duration of Study 1.

Our inclusion criteria were as follows: 55+ years of age, fluent in English, normal or corrected-to-normal eye vision, and no diagnostic history of a cognitive condition (e.g., mild cognitive impairment) or a mental health condition (e.g., depression, anxiety) according to self-report. Participants were only enrolled in the intervention if they did not report proficiency in any of the three skills being taught in the intervention: Spanish, painting, and iPad. Proficiency was defined as having more than a year of experience with any of the three skills in the past 10 years or more than 5 years of experience within the past 50 years. In addition, there was no difference in Mini-Mental State Examination (MMSE) scores between the control group and intervention group ($t(13) = 0.649$, $p = .527$; Table 1). For each assessment that was completed (up to three: pre-test, midpoint, and post-test), participants were compensated $40. This study was pre-registered on ClinicalTrials.gov (Protocol Record 1320181).

Intervention procedures

The following procedures only applied to the intervention group. After being screened, the intervention group was invited to an orientation session 1 week before the start of the intervention. At the orientation session, the senior author provided an overview of the intervention procedures, and the intervention participants were introduced to each other and the research team. Including this orientation session probably increased adherence to the program (Goldberg & Kiernan, 2005).

We selected the intervention skills based on comments from the aforementioned focus group, which indicated that they would be interested in learning practical skills for daily functioning (e.g., iPad, Spanish). To encourage the intense learning experience faced by younger age groups, we included skills that had the potential for increasing levels of depth and challenge, some taking years to master. We selected the final three skills from the list of potential skills based on these criteria and instructor availability. These three skills all include the use of cognitive control, episodic memory, and working memory (e.g., Adesope, Lavin, Thompson, & Ungerleider, 2010; Bak, Long, Vega-Mendoza, & Sorace, 2016; Chamberlain, 2018; Chan et al., 2016; Service & Craik, 1993). All participants assigned to the intervention condition were enrolled in all three of these classes, without variation.

The intervention included three 2-hr classes (Spanish, painting, and iPad), which met on a weekly basis, two on one day, and one on the next day. The classes were held at the University of California, Riverside's Osher Lifelong Learning Institute (OLLI). The intervention participants received complimentary refreshments, as well as painting supplies, a Spanish textbook (including online codes), and a loaned 9.7" iPad (fifth generation). In each class, instructors lectured on various topics and involved participants in class assignments and group exercises (full syllabi are available at http://callalab.com/research/interventions/). Various topics were covered for each class, including the Spanish alphabet, pronunciation, and verbs for the Spanish class, blending colors, contouring, and painting still life for the painting class, and planning a trip using apps for the iPad class. The three qualified class instructors (based on years of teaching experience and academic degrees) were over the age of 55 and encouraged to take part in the classes that they were not teaching. Two of the instructors learned their respective skills after retirement to demonstrate to the participants that these skills can be acquired in later life.

In addition to these three classes, the senior author led a "coffee talk" discussion session after the third class each week. These sessions included lectures on motivation, growth mindset, scientific literacy, and neuroplasticity, and included group discussions on successful aging and barriers to learning and resilience in old age. Finally, all participants created a long-term learning plan at the end of the intervention to indicate how they would continue learning new skills after the intervention (a behavior change technique known as "action planning," Michie, Johnston, Francis, Hardeman, & Eccles, 2008).

Measures

Table 2 includes the measures from the assessment battery relevant to this article, which assessed cognitive abilities that were important for learning the three skills. The cognitive battery included the standardized NIH EXAMINER assessments (https://memory.ucsf.edu/examiner) on working memory (dot-counting and 1-back) and cognitive control (Flanker and set shifting; Kramer et al., 2014). The dot-counting task required the participants to count the number of colored dots among other colored shapes and then remember the number of dots across a series of trials. The 1-back task required participants to remember locations of squares on the previous trial with an intervening number naming task. The Flanker task required participants to identify the direction of an arrow among arrows either facing or not facing the same direction as the target arrow. The set-shifting task required participants to sort colored shapes based on shape or color. The EXAMINER was administered via a desktop computer with a 19-inch computer screen, with participants sitting approximately 64 cm away. Responses to these tasks were automatically recorded via PsychoPy (version 7.1) software. An R script provided by the EXAMINER development team calculated

Table 1. Study 1 and 2 Baseline Characteristics

	Study 1		Study 2
Characteristic	Intervention, $N = 6$	Control, $N = 9$	Intervention, $N = 27$
Age, $M \pm SD$ (range)	66.33 ± 6.41 (58–74)	70.22 ± 9.97 (58–86)	69.44 ± 7.12 (58–86)
Females, N (%)	4 (67)	6 (67)	18 (67)
Race, N (%)			
White	5 (83)	6 (67)	18 (67)
Black	1 (17)	2 (22)	4 (15)
Asian	0 (0)	0 (0)	1 (4)
Multiracial or Other	0 (0)	1 (11)	4 (15)
Ethnicity, N (%)			
Hispanic	0 (0)	1 (11)	3 (11)
Non-Hispanic	6 (100)	8 (89)	24 (89)
Years of education, $M \pm SD$ (range)	16.50 ± 3.56 (14–23)	15.22 ± 2.33 (13–20)	15.56 ± 2.90 (12–20)
Retired, N (%)	5 (83)	7 (78)	22 (81)
Marital status			
Married or partner	3 (50)	2 (22)	19 (70)
Widowed	1 (17)	2 (22)	5 (19)
Separated or divorced	1 (17)	3 (33)	1 (4)
Never married	1 (17)	2 (22)	1 (4)
Prefer not to answer	0 (0)	0 (0)	1 (4)
Living arrangement			
Living alone	2 (33)	7 (78)	5 (19)
Live with spouse/partner	3 (50)	1 (11)	20 (74)
Live with other family	0 (0)	1 (11)	1 (4)
Live with someone else	1 (17)	0 (0)	1 (4)
Income			
Less than \$20,000	1 (17)	1 (11)	1 (4)
\$20,000 to \$29,999	1 (17)	2 (22)	3 (11)
\$30,000 to \$39,999	0 (0)	1 (11)	1 (4)
\$40,000 to \$49,999	0 (0)	0 (0)	1 (4)
\$50,000 to \$99,999	2 (33)	4 (44)	11 (41)
\$100,000 to \$199,999	2 (33)	0 (0)	4 (15)
\$200,000 and over	0 (0)	1 (11)	1 (4)
Prefer not to answer	0 (0)	0 (0)	5 (19)
MMSE score ± SD (range)	28.33 ± 2.25 (25–32)	27.67 ± 1.73 (24–30)	26.52 ± 3.17 (19–30)

Notes: M = mean; MMSE = Mini-Mental State Examination; SD = standard deviation.

a composite score based on reaction time and accuracy in all tasks, as well as a composite score for the working memory tasks and the cognitive control tasks separately. To measure episodic memory, the Rey Auditory Verbal Learning Test (RAVLT; Schmidt, 1996), required participants to memorize a list of words. The RAVLT was administered verbally and audio-recorded for later coding accuracy. The number of words recalled was averaged over six trials: five repeated prompts of the same list and one prompt from a different list. Total RAVLT scores were divided by 6, the number of trials. Therefore, a perfect score would have been 15.

The functional independence measure, Everyday Problems Test (EPT; Willis & Marsiske, 1993), was a 40- and 42-item written test (Version A had 42 items, and Version B had 40 items), including questions on daily tasks such as analyzing recipes, nutritional labels, and medicinal dosage. The EPT was included to have increased sensitivity to demonstrate improvements in nondemented populations, unlike the independent activities of daily living (IADL) questionnaire. Indeed, healthy older adults are typically identified based on their perfect or near-perfect IADL score, as they were in our study. To measure adherence during the intervention, participants' attendance was recorded in class, and homework hours that were completed outside of class were logged by the participants on paper or on Google Sheets. Hours of engagement in the intervention included both attendance and homework hours.

Both the intervention and no-contact control groups completed cognitive and functional independence assessments at pre-test (Week 0), midpoint (Week 8), and post-test (Week 15). The no-contact control group did not participate in any intervention classes. Each assessment battery lasted approximately 1.5 to 2 hr.

Statistical analyses of cognitive and functional outcomes

We fit separate linear mixed-effects regression models to each outcome: the composite cognitive score (composed of both working memory and cognitive control), working

Table 2. Outcome Measures From Study 1 and Study 2

		Time Point			
Measure	Duration	Pre-test	Midpoint	Post-test	Mode of administration
Feasibility outcomes					
Intervention adherence					
Class attendance	N/A	X+	X+	X+	Observation
Hours spent on class homework	N/A	X+	X+	X+	Handwritten/computer
Intervention outcomes					
Daily functioning					
IADL	5	+		X+	Interview
Everyday Problems Test*	30	X+	+	+	Handwritten
Cognitive control					
NIH EXAMINER: Flanker	5	X+	X+	X+	Computer
NIH EXAMINER: Set shifting	10	X+	X+	X+	Computer
Working memory					
NIH EXAMINER: dot-counting	5	X+	X+	X+	Computer
NIH EXAMINER: 1-back	10	X+	X+	X+	Computer
NIH EXAMINER: 2-back	10	+	+	+	Computer
WAIS-III Digit Span Task	5	+	+	+	Handwritten
Verbal episodic memory					
RAVLT	10	X+	X+	X+	Interview
Content knowledge					
Spanish test	15	X+		X+	Handwritten
iPad test†	15	X+		X+	Handwritten
Drawing test	15	+		+	Handwritten
Painting test	15	X		X	Handwritten
Music composition test	15	+		+	Handwritten
Photography test	15	+		+	Handwritten

Notes: IADL = independent activities of daily living; N/A = not applicable; NIH = National Institutes of Health; RAVLT = Rey Auditory Verbal Learning Test; WAIS-III = Wechsler Adult Intelligence Scale, Third Edition.
*Same version was administered at pre- and post-test for Study 2. X indicates that a measure was administered for Study 1. + indicates that a measure was administered for Study 2. † indicates that a different measure was used for Study 1 and Study 2.

memory, cognitive control, and episodic memory. These models account for the fixed (i.e., population-level effects) and random effects (i.e., subject-level effects) of the study, to determine whether simultaneously learning multiple novel skills (i.e., the intervention group) would increase cognitive outcomes compared with a group of individuals who did not participate in the intervention classes (i.e., no-contact control group). The normality assumption was checked in all models, and when this assumption was violated, we performed transformations to the outcome measure to achieve the normally distributed residuals. Bonferroni corrections were not applied for the separate models because Bonferroni correction is only needed when a general null hypothesis is of interest (i.e., all of the null hypotheses are true simultaneously; Perneger, 1998). In each mixed-effects model, we included time (0—pre, 1—mid, 2—post), group (0—intervention and 1—control), sex (0—male, 1—female), retirement status (0—no, 1—yes), age, MMSE score, and interactions between categorical variables. Time was included as a categorical variable creating two dummy variables (for midpoint and for post-test, using pre-test as the control time point), which allowed for changes in the response to be different between time points. Predictors, other than time and intervention group, were systematically removed to find the optimal model for each outcome. For each outcome, results from the model with significant variables and the smallest Akaike information criterion (AIC) are presented in the tables. For transparency, the Results section reports all significant and marginally significant effects among these predictors.

Results

Adherence

In terms of adherence, the average number of hours spent on assignments outside of class was 122.68 (SD = 50.16, range = 47.26–197.76; approximately 8.18 hr per week), and the average number of hours spent in class was 91.46 (SD = 9.71, range = 74.50–104.50, approximately 6.10 hr per week), for a total of 14.28 hr per week on average. Examples of participants' paintings to demonstrate progress and adherence during the painting class are displayed in Figure 2.

Cognitive outcomes

Composite cognitive score (EXAMINER)

For the composite cognitive EXAMINER score, the midpoint scores were 0.237 units higher than the pre-test scores on average (p = .028), and the post-test scores were .261 units higher than the pre-test scores (p = .022), but there was no difference between groups (Figure 4; Tables 3 and 4).

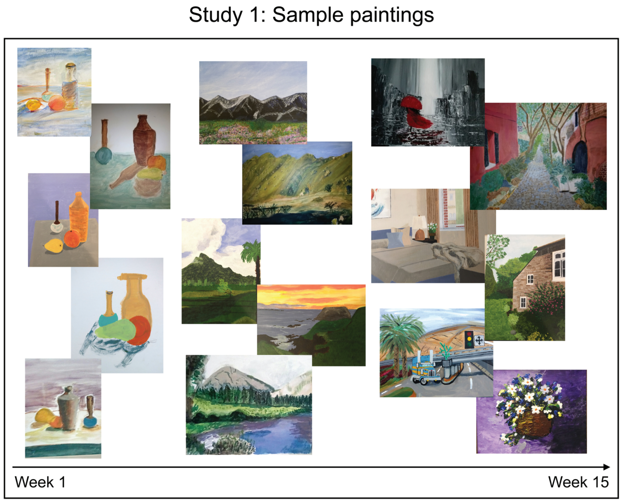

Figure 2. Sample paintings from intervention participants in Study 1.

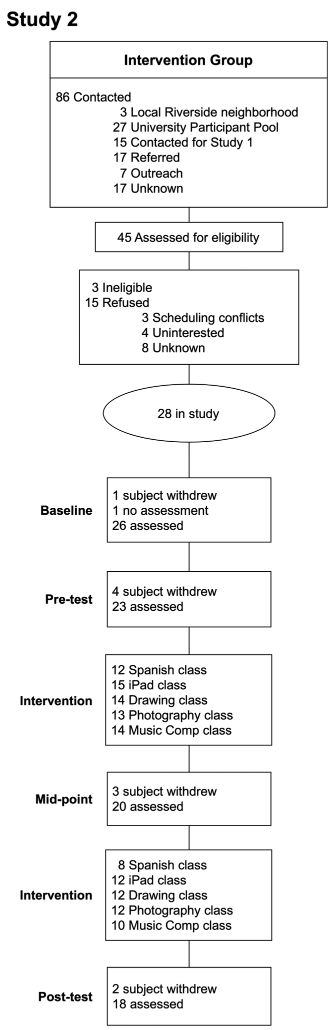

Figure 3. The number of individuals throughout the duration of Study 2.

Cognitive control (EXAMINER)

For the cognitive control component, results are reported in Table 4. The post-test × sex interaction was significant (p = .013). Males exhibited a higher mean score at post-test compared with pre-test (p < .001). Further exploration of differences between time points showed that males exhibited a higher mean score at midpoint compared with pre-test (p = .006), although the difference between midpoint and post-test was not significant (p = .152).

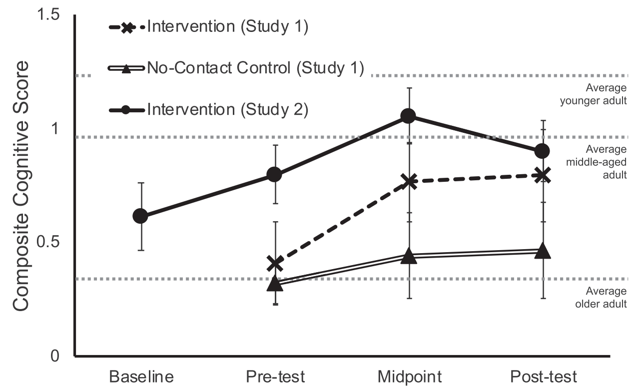

Figure 4. Composite cognitive scores from Study 1 (intervention and control group) and Study 2 (intervention group). The highest dotted line represents the mean of a cross-sectional convenience sample of younger adults (n = 28, M = 19.07 years, SD = 1.05, range = 18–22) completing the same cognitive tasks, with a mean EXAMINER composite score of 1.21 (SD = 0.62, range = 0.17–2.96). The middle dotted line represents the mean of a cross-sectional convenience sample of middle-aged adults (n = 22, M = 42.36 years, SD = 5.79, range = 35–51) with a mean EXAMINER composite score of 0.98 (SD = 0.62, range = −0.37 to 2.10), and the lowest dotted line represents the mean of a separate cross-sectional convenience sample of older adults (n = 43, M = 70.17 years, SD = 9.34, range = 53–89), with a mean EXAMINER composite score of 0.33 (SD = 0.57, range: −1.45 to 1.39). Error bars represent ±1 SE. M = mean; SD = standard deviation; SE = standard error.

Working memory (EXAMINER)

For the working memory component of the composite EXAMINER score, results are also reported in Table 4. Scores at midpoint were higher than pre-test (p = .010, Table 4), but there were no group differences. The mean score increased by 0.394 units at midpoint compared with pre-test. The MMSE score was a marginally significant predictor (p = .087), indicating that as the MMSE score increased by one unit, the working memory score was estimated to increase by 0.112 units.

Episodic memory (RAVLT)

The average RAVLT scores are listed in Table 3, and model outcomes are listed in Table 5. The midpoint time × group interaction was significant (p = .012, Table 5). For the control group, midpoint scores increased by 1.588 units on average from pre-test (p = .001), and post-test scores increased by 1.155 units from pre-test (p = .024). No difference between midpoint and post-test scores was observed (p = .425). For the intervention group, the mean scores at post-test were significantly higher than those from pre-test by 1.416 units on average (p = .044), and the scores from post-test were significantly higher than those from midpoint by 1.039 units (p = .035). In addition, the MMSE score predicted average RAVLT scores (p = .040): the average RAVLT score was estimated to increase by 0.546 units for every increased unit of the MMSE score.

Functional outcome

Everyday Problems Test

The intervention group increased in their EPT scores by 12% on average from 74.23% at pre-test to 86.19% at post-test (M_{diff} = 12%, SD_{diff} = 12%, range = −1% to 31% change),

Table 3. Mean and Standard Error of the Composite Cognitive Scores, Component Cognitive Scores, RAVLT Scores, and Digit Span Scores From Study 1 (Intervention and Control Groups) and Study 2 (Intervention Group)

Score	Baseline	Pre-test	Midpoint	Post-test
Study 1 Intervention group				
Composite Cognitive	n/a	0.41 (0.18)	0.77 (0.17)	0.79 (0.20)
Cognitive Control	n/a	0.23 (0.17)	0.49 (0.21)	0.60 (0.24)
Working Memory	n/a	0.30 (0.09)	0.76 (0.23)	0.37 (0.12)
RAVLT	n/a	9.36 (0.44)	10.67 (0.71)	10.23 (0.61)
Study 1 Control group				
Composite Cognitive	n/a	0.32 (0.09)	0.44 (0.19)	0.46 (0.21)
Cognitive Control	n/a	0.15 (0.06)	0.21 (0.14)	0.29 (0.21)
Working Memory	n/a	0.03 (0.21)	0.37 (0.22)	0.24 (0.27)
RAVLT	n/a	8.98 (0.83)	8.93 (0.80)	10.06 (0.82)
Study 2 Intervention group				
Composite Cognitive	0.61 (0.15)	0.80 (0.13)	1.06 (0.12)	0.90 (0.13)
Cognitive Control	0.48 (0.12)	0.53 (0.11)	0.81 (0.10)	0.69 (0.12)
Working Memory	0.04 (0.15)	0.33 (0.14)	0.72 (0.14)	0.61 (0.12)
RAVLT	8.22 (0.43)	9.19 (0.44)	10.42 (0.50)	11.44 (0.50)
Digit Span	1.30 (0.05)	1.31 (0.07)	1.34 (0.05)	1.32 (0.06)

Note: n/a = not applicable; RAVLT = Rey Auditory Verbal Learning Test; *SE* = standard error. *SE* reported in parentheses.

Table 4. Results of the Mixed Effects Model for the Composite Cognitive, Cognitive Control, and Working Memory Scores From Study 1

Predictor	Estimate	Standard error	95% CI	*df*	Unadjusted *p*-value
Composite Cognitive Scores					
Midpoint	0.237	0.101	[0.029, 0.446]	25	.028
Post-test	0.261	0.107	[0.041, 0.481]	25	.022
Group	−0.264	0.235	[−0.772, 0.245]	13	.145
Cognitive Control Scores					
Midpoint	0.792	0.289	[0.225, 1.360]	14	.016
Post-test	1.270	0.267	[0.747, 1.794]	14	<.001
Group	−0.395	0.279	[−0.942, 0.153]	11	.185
Sex	0.517	0.296	[−0.063, 1.096]	11	.108
Midpoint × sex	−0.553	0.365	[−1.269, 0.162]	14	.152
Post-test × sex	−0.966	0.340	[−1.633, −0.300]	14	.013
Working Memory Scores					
Midpoint	0.394	0.140	[0.105, 0.683]	25	.010
Post-test	0.100	0.145	[−0.199, 0.400]	25	.496
Group	−0.211	0.226	[−0.703, 0.281]	12	.368
MMSE score	0.112	0.060	[−0.019, 0.242]	12	.087

Notes: CI = confidence interval; *df* = degrees of freedom; MMSE = Mini-Mental State Examination; RAVLT = Rey Auditory Verbal Learning Test.

whereas the control group declined in their EPT scores on average from 81.11% at pre-test to 78.62% at post-test (M_{diff} = -2%, SD_{diff} = 12%, range = −22% to 16% change). However, using the predetermined predictors (time, group, sex, retirement status, age, MMSE score, and interactions between categorical variables), none of the models that we fit to the EPT scores could sufficiently explain the data.

Discussion

Study 1 established the feasibility of conducting an intervention requiring older adults to learn three real-world skills simultaneously for approximately 15 hr per week. Our enrollment, adherence, and retention rates were similar to those of Park and colleagues (2014), which included learning one skill at a time. The intervention and control groups did not significantly differ in terms of cognitive abilities (perhaps due to small sample sizes) except for the RAVLT scores, largely replicating Park and colleagues (2014).

Study 2

Study 2 increased the sample size to increase the power to detect changes over time. Because the aim of Study 2 was to refine the intervention procedure and replicate the results of the intervention group from Study 1 and to maximize our power, we assigned all recruits to the intervention group. The study

Table 5. Results of the Mixed Effects Model for the Average RAVLT Scores From Study 1 and Study 2

Predictor	Estimate	Standard error	95% CI	*df*	Unadjusted *p*-value
Study 1					
Midpoint	1.588	0.467	[0.672, 2.504]	22	.003
Post-test	1.155	0.511	[0.153, 2.157]	22	.034
Group	0.263	0.929	[−1.558, 2.084]	12	.782
MMSE score	0.546	0.237	[0.081, 1.010]	12	.040
Midpoint × group	−1.645	0.602	[−2.824, −0.466]	22	.012
Post-test × group	−0.172	0.678	[−1.501, 1.156]	22	.801
Study 2					
Pre-test	0.758	0.352	[0.053, 1.463]	59	0.036
Midpoint	1.969	0.301	[1.367, 2.572]	59	<0.001
Post-test	2.981	0.295	[2.391, 3.570]	59	<0.001
MMSE score	0.340	0.114	[0.104, 0.576]	24	0.007
Sex	1.529	0.742	[−0.003, 3.061]	24	0.050

Notes: CI = confidence interval; *df* = degrees of freedom; MMSE = Mini-Mental State Examination; RAVLT = Rey Auditory Verbal Learning Test.

also tested the feasibility of scaling up the intervention from 6 to 27 participants. In such feasibility trials, no control group is required (Rebok, 2016). However, intervention participants did serve as their own control by completing a baseline assessment 4–6 weeks prior to the start of the intervention.

Method

Participants

Twenty-eight older adults were initially recruited to participate in the study, with 27 participants providing data (18 females, *M* = 69.44 years, *SD* = 7.12, range = 58–86; Table 1, Figure 3). Eighteen participants (13 females, *M* = 70.39 years, *SD* = 7.24, range = 59–86) completed the full 12-week intervention. A total of nine participants (five females, four males, *M* = 67.56 years, *SD* = 6.88, range = 58–79) withdrew from the study after baseline due to scheduling conflicts, severe medical issues, family commitments, or undisclosed reasons. Of these nine, four withdrew before providing pre-test data, three before providing midpoint data, and two withdrew before providing post-test data (Figure 1). The completion rate was 18 of 27 participants enrolled, or 68%, which is lower than that of Park and colleagues (2014).

Participants were screened over the telephone, following Study 1, except that participants with prior mild mental health conditions (e.g., episodes of depression and anxiety prior to the intervention but not currently experiencing symptoms) could be enrolled. Study 2 also included more detailed screening criteria for proficiency in the intervention skills: proficiency was determined over the telephone based on self-report ratings on a Likert scale from 1 (no experience with a skill) to 5 (a lot of experience with a skill). If a participant rated themselves as 3, 4, or 5 for any of the skills, they were considered proficient in that skill and were not assigned to its respective class. Spanish proficiency was additionally tested with a short quiz administered in Spanish (e.g., answering "how old are you?"), given the prevalence of Spanish language in Southern California. Individuals were assigned to the Spanish class if they answered fewer than two questions correctly, regardless of their self-report ratings. Participants were recruited in the same way as the participants in Study 1. The screening-to-enrollment ratio was 62.22%.

In addition to these participants, one of the six participants from Study 1's intervention group audited three classes offered through Study 2, which was part of this participant's long-term plan to continue learning new skills. All participants in Study 1's control group also were given the option of auditing classes from Study 2. Three individuals from the Study 1 control group audited at least three classes in Study 2: one audited four classes, and two audited three. Assignment to three classes was pseudorandomized. The data from these control participants from Study 1 were not included in the final analyses for Study 2. This study was pre-registered on the Open Science Framework: https://osf.io/7msw4/?view_only=29de500f84114126889117a7ae284860.

Measures

A baseline assessment (Week 0) was added in Study 2, so that the participants could serve as their own control. We also included pre-test (Week 6), midpoint (Week 12), and post-test (Week 18) assessments, following Study 1. The measurement battery for Study 2 was identical to the battery in Study 1, with the exception of two additional working memory measures: the 2-back from the EXAMINER battery (Kramer et al., 2014), and the forward and backward digit span task (Table 2). The 2-back task required participants to remember the location of a square on two trials prior to the current trial (compared with only one trial prior in the 1-back task). The forward and backward digit span task required participants to memorize 16 sequences for the forward task and 14 sequences for the backward task. There were two sequences per trial, with eight trials for the forward task and seven trials for the backward task. The number of digits in each sequence increased after each trial, starting with two digits in the sequences for the first trial and ending with eight to nine digits in the last trial. The total score was divided by 15, the total number of trials.

Intervention procedures

The intervention procedures for Study 2 were similar to those used in Study 1 with several key differences outlined here. The intervention was shortened from 15 to 12 weeks based on feedback from Study 1 participants and increased absences in the

last 3 weeks in Study 1, mostly due to personal scheduling commitments. The orientation session and classes were held at the Center for Ideas and Society, located on UCR's main campus.

Participants in Study 2 were pseudorandomized to three out of five classes (i.e., drawing, Spanish, photography, music composition, and iPad) to reduce class sizes and balance the number of participants enrolled in each class and combination of classes, while accounting for individuals' experiences with each skill. The two classes new to Study 2 (photography and music composition) also utilize cognitive control and working memory, as do the three skills included in Study 1 and Study 2 (e.g., Lynch & LaGasse, 2016; Park et al., 2014). To avoid attrition due to being assigned to classes that they did not prefer to take, all participants were given the option to enroll in all five classes, as long as they still enrolled in the three classes to which they were initially assigned. Therefore, participants could choose whether they wanted to enroll in one or two classes in addition to the three classes to which they were pseudo-randomly assigned. Eight participants elected to do so: five enrolled in four classes and three enrolled in all five classes. Three classes were offered on one day, and two classes on the next day.

Weekly discussion sessions, similar to the "coffee talks" from Study 1, were led by the senior author. Similar to Study 1, these sessions included lectures on motivation, growth mindset, scientific literacy, and neuroplasticity, and included group discussions on successful aging and barriers to learning and resilience in old age. Unlike Study 1, these sessions were held during the lunch hour with lunch provided to the participants. To maintain small class sizes, there were two weekly discussion lunch sessions, and participants were assigned to one of the two sessions depending on their class schedules.

All participants received general class supplies (e.g., pencils, notebooks) and a loaned iPad (9.7" iPad Pro; 2 participants used their own iPads that were similar to the model used by the other participants). Depending on the classes that the participants were assigned to, they also received a Spanish textbook, a photography textbook, and drawing supplies. Unless they had a UCR parking pass already ($n = 2$), participants received UCR parking passes which cost \$130 or \$158, depending on the type of permit required, whereas parking was \$30 total in Study 1. Those with handicap placards were able to park near the building, while others were required to walk 0.25 miles uphill from the parking lot to the center. Some participants self-arranged carpools during the intervention.

For this study, the drawing and iPad instructors were from Study 1, and the three new instructors were qualified UCR affiliates (e.g., graduate students or lecturers). The Spanish and iPad classes for Study 2 included the same topics that were covered in Study 1. The drawing class closely resembled the painting class from Study 1, in that participants were taught similar concepts (e.g., perspective, still life). For the photography class, lessons covered topics such as lighting, composition, and texture. The music composition class included, but was not limited to, lessons on reading music, the physics of sound, and altering pre-recorded music. All syllabi are located in the link provided in the Study 1 Method section. Last, participants logged on paper or online the number of hours they spent per day working on assignments outside of class.

Results

Following the same process as Study 1, we fit separate mixed-effects models to each outcome (composite cognitive score, working memory, cognitive control, episodic memory, and digit span) to evaluate the effects of the intervention, while controlling for demographic variables, including sex and MMSE score. Analyses procedures (e.g., use of transformations when the normal distribution assumption was violated) were identical to Study 1. Time was included as a categorical variable leading to three dummy variables (for pre-test, midpoint, and post-test, keeping baseline as the control time point). For each outcome, the model with significant variables and the smallest AIC is presented in the tables and its significant effects are described. The means and standard deviations for each cognitive measure at each time point are included in Table 3. To obtain a more comprehensive understanding of how participants from Study 1 and Study 2 compared in cognition relative to young adults, middle-aged adults, and other older adults, cross-sectional cognitive data were obtained (Figure 4).

Cognitive outcomes

Composite cognitive score (EXAMINER)

Results of the linear mixed-effects model testing the mean composite cognitive scores of the participants in the intervention group over time are reported in Table 6 and illustrated in Figure 4. Importantly, scores were significantly higher at midpoint ($p < .001$) and post-test ($p = .011$) relative to baseline, 4–6 weeks prior to the start of the intervention. Also, relative to baseline, scores at pre-test, when the intervention began, were marginally higher ($p = .099$), suggesting a slight practice effect. We also conducted additional Wald tests to compare pre-test, midpoint, and post-test scores to each other. We found a marginally statistically significant difference between mean scores measured at pre-test and midpoint: Mean scores increased by 0.150 units from pre-test to midpoint ($p = 0.081$). This overall finding follows the trend we found in the intervention group in Study 1, which did not include a baseline.

MMSE score was a significant predictor ($p = .037$): as the MMSE score increased by one unit, the composite cognitive score was predicted to increase by 0.081 units.

Cognitive control (EXAMINER)

Cognitive control results are reported in Table 6. There was a significant increase in mean scores from baseline to midpoint ($p = .008$), and a significant increase in scores from baseline to post-test ($p = 0.46$). We performed additional Wald tests to compare pre-test, midpoint and post-test time points to each other. We found a statistically significant difference between mean scores measured at pre-test and midpoint: Mean scores increased by 0.195 units ($p = 0.021$).

Working memory (EXAMINER)

Working memory scores increased from baseline to pre-test ($p = .039$), baseline to midpoint ($p \leq .001$), and baseline to post-test ($p = .001$; Table 6). We performed additional Wald tests to compare pre-test, midpoint, and post-test time points to each other. There was a significant increase of 0.378 units from pre-test to midpoint working memory scores ($p \leq .001$) and a significant increase of 0.199 units between pre-test and post-test ($p = .044$). Finally, between midpoint and post-test, there was a marginal decrease of 0.179 units on average ($p = .064$). The total number of hours spent on intervention activities predicted working memory scores ($p = .002$). In addition, gender and MMSE scores were significant predictors ($p = .019$) and ($p = .003$), respectively.

Episodic memory (RAVLT)

Episodic memory scores also are reported in Table 6. There was a significant increase of 0.758 units in RAVLT scores from baseline to pre-test (p = .036), and a significant increase of 1.969 units in RAVLT scores from baseline to midpoint (p < .001), and from baseline to post-test, (2.981 units, p < .001). We performed additional Wald tests to compare pre-test, midpoint, and post-test time points to each other. From pre-test to midpoint, mean scores significantly increased by 1.212 units (p < .001). From pre-test to post-test, mean scores increased by 2.223 units (p < .001), and from midpoint to post-test, mean scores increased by 1.011 units (p < .001).

MMSE score was a significant predictor (p = .007), indicating that as MMSE score increased by one unit, the RAVLT score was estimated to increase by 0.340 units.

There was also a main effect of sex, where males had a significantly lower RAVLT score (1.529 units) than females (p = .050) on average.

Digit span

Although scores did not differ across the time points, total hours spent in the intervention was a significant predictor (p = .013). With every additional hour spent on training activities, the average digit span was estimated to increase by 0.001 units (Table 6).

EXAMINER in cross-sectional samples as reference points

For reference points, separate samples of young adults (n = 28, M = 19.07 years, SD = 1.05, range = 18–22), middle-aged adults (n = 22, M = 42.36 years, SD = 5.79, range = 35–51), and older adults (n = 43, M = 70.17 years, SD = 9.34, range = 53–89) were assessed using the EXAMINER cognitive battery in one occasion (i.e., baseline) and did not participate in the intervention. The mean EXAMINER composite score for young adults was 1.21 (SD = 0.62, range = 0.17–2.96). The mean EXAMINER composite score for middle-aged adults was 0.98 (SD = 0.62, range = −0.37 to 2.10), and the mean of a cross-sectional convenience sample of older adults who did not participate in the intervention was .33 (SD = 0.57, range = −1.45 to 1.39).

Functional outcome

Everyday Problems Test

From pre-test to post-test, EPT scores increased from 82.46% to 88.27% (SD = 6.38%, range: -5% to 12% change). However, using the predetermined predictors, none of the models that we fit to the EPT scores could sufficiently explain the data.

Content knowledge outcome

In general, participants increased in their knowledge of the content taught in the classes. The participants did not receive their scores or feedback on these exams during the intervention. In Spanish, participants increased from understanding on average 37% of the questions on the exam to 87% ($t(10)$ = 4.53, p = .001). In Drawing, participants increased on average from 23.46% to 29.06% on the exam, although this difference was not significant ($t(14)$ = 1.60, p = .133). Although their understanding of drawing concepts may not have increased much, their drawing ability did increase considerably, similar to increases in painting ability from Study 1 (Figure 2). Therefore, objective tests of drawing vocabulary may not have mapped onto increases in drawing ability, which

Table 6. Results of the Mixed-Effects Model for the Composite Cognitive, Working Memory, Cognitive Control, and Digit Span Scores From Study 2

Predictor	Estimate	Standard error	95% CI	*df*	Unadjusted *p*-value
Composite Cognitive Scores					
Pre-test	0.184	0.110	[−0.036, 0.404]	55	.099
Midpoint	0.334	0.080	[0.174, 0.494]	55	<.001
Post-test	0.279	0.106	[0.067, 0.492]	55	.011
MMSE score	0.081	0.037	[0.005, 0.156]	20	.037
Cognitive Control Scores					
Pre-test	0.051	0.093	[−0.136, 0.237]	49	.588
Midpoint	0.245	0.089	[0.068, 0.423]	49	.008
Post-test	0.198	0.097	[0.004, 0.392]	49	.046
Working Memory Scores					
Pre-test	0.292	0.138	[0.016, 0.568]	37	.039
Midpoint	0.670	0.138	[0.393, 0.946]	37	<.001
Post-test	0.491	0.137	[0.216, 0.766]	37	.001
Hours	0.003	0.001	[0.001, 0.004]	17	.002
MMSE	0.097	0.028	[0.039, 0.156]	17	.003
Gender	−0.449	0.176	[−0.816, −0.081]	17	.019
Average Digit Span Scores					
Pre-test	0.024	0.045	[−0.065, 0.113]	58	.599
Midpoint	0.053	0.038	[−0.022, 0.129]	58	.168
Post-test	0.021	0.031	[−0.040, 0.082]	58	.499
Hours	0.001	0.000	[0.000, 0.002]	22	.013

Notes: CI = confidence interval; *df* = degrees of freedom; MMSE = Mini-Mental State Examination.

has procedural components. In Photography, participants increased slightly from 69% to 73%, although this difference was not significant ($t(14) = 0.77$, $p = .453$). In Music Composition, participants increased significantly from 7% to 55% ($t(13) = 11.84$, $p < .001$). In iPad class, participants increased slightly from 41% to 45% in terms of their knowledge about various icons, although this difference was not significant ($t(12) = 1.49$, $p = .162$). The participants did become more proficient at navigating the iPad. Although participants did numerically increase their scores on average on these objective knowledge tests, including more procedural tests for drawing, photography, and iPad probably would be a more accurate representation of what the participants had learned.

General Discussion

Building on prior real-world skill-learning interventions that included learning one skill at a time, we investigated the feasibility of conducting an intervention that included simultaneously learning multiple real-world skills, and the impact of doing so on cognitive abilities (working memory, cognitive control, episodic memory) and functional independence in older adults. The learning experiences in our intervention align with those from younger adulthood (e.g., undergraduates enrolled in three to five classes per quarter/semester). We hypothesized that broad cognitive and functional gains would result from such intense, novel broad learning experiences. In the first study, participants learned Spanish, painting, and how to use an iPad for 15 weeks. In the second study, participants were assigned to learn three out of five skills (Spanish, drawing, how to use an iPad, music composition, and photography), but could opt to enroll in up to five classes for 12 weeks.

Overall, the results from Study 1 and Study 2 showed a general trend of increased cognitive abilities across a broad range. For example, by Week 6 (midpoint), intervention participants from Study 2 significantly increased their working memory, cognitive control, and episodic memory from baseline: the midpoint performance for those intervention participants was similar to performance of a separate sample of middle-aged adults 30 years younger. There also were some sex effects, which should be replicated, along with our main findings.

Anecdotal evidence from participants' testimonies at the end of the intervention provided additional insight to the impact of the intervention. Several intervention participants stated that learning multiple new skills simultaneously took them out of their routines and comfort zones. Painting/drawing, photography, and music composition students noted that they began to see and hear things in new ways. iPad students reported that they gained confidence with technological devices in general, and some noted that they were able to teach their grandchildren new ways of using the iPad, instead of the other way around. The intervention participants also seemed to have acquired a "fear of missing out", which is a characteristic of younger populations, and thought to not be reflective of older populations (e.g., Carstensen, 2006; Przybylski, Murayama, DeHaan, & Gladwell, 2013). For instance, the intervention participants became worried that they would miss out on important information when they could not attend a class. In general, the intervention participants reported feeling pleasantly surprised at their accomplishments during the intervention, and that they became fearless towards new learning challenges by the end of the intervention. The intervention participants from both studies have continued to meet approximately once a month after post-test. Although these outcomes are based on anecdotal evidence, future studies could include assessments to formally measure these sociomotivational effects. Doing so would provide a better understanding of which factors are unique to particular age groups, and which ones are outcomes of an intense, encouraging, learning environment with appropriate resources, such as helpful instructors.

A few design characteristics limit conclusions that we can draw from our data. Given that we recruited convenience samples from the community, results may not generalize to individuals who are not willing and/or are unable to participate in an intensive 3-month intervention, which may exclude individuals who have lower income and cannot afford to retire. However, our sample does include a wide range of income and education levels, although general motivation level based on adherence was high. The relatively high dropout rate in Study 2 also indicates that this intervention, as currently designed, cannot be applied to all older adults, especially those with severe cognitive or physical health problems and/or little time due to many personal commitments. Our intervention was demanding given the requirement of learning skills simultaneously, which may have led to the higher drop-out rate.

Our relatively small sample sizes did not provide enough power to investigate the effects of certain variables, such as class combinations to determine which classes, if any, may have been driving the overall effects. However, the purpose of the study was to test the feasibility and general effects of learning multiple skills simultaneously, rather than identifying specific classes that would lead to the most improvement. Increasing sample sizes for our intervention would allow future research to investigate the impact of learning three, four, or five skills simultaneously, as well as the differential impact of variety versus frequency of activities (cf. Bielak, Mogle, & Sliwinski, 2019; Carlson et al., 2012). It is important to note that our studies were designed to be feasibility studies (i.e., small sample sizes), given the novel intervention procedures. However, we did conduct Study 2 (with a larger sample size compared to Study 1) with the aim to replicate the findings from the intervention group from Study 1. Until a larger intervention is conducted with active control groups, such as learning only one skill at a time, it is unclear what the key "active ingredients" of our intervention are. At this point, we can only conclude that it is feasible to conduct an intervention involving learning multiple new real-world skills with older adults and that there may be significant potential in doing so. Based on our current findings, future interventions can investigate the mechanisms driving the overall effects.

The present studies provide early evidence that intense learning experiences akin to those faced by younger populations are possible in older populations and may facilitate gains in cognitive abilities. The primary purpose of our study was to expose older adults to a novel, intense learning environment and show them how to learn new difficult skills that may seem insurmountable initially, even if they learned less overall in some of the skills compared with other skills. Our research team has proposed elsewhere (Nguyen et al., 2020; Wu et al., 2017) that cognitive aging research may benefit by applying child and emerging adult development approaches to older adulthood. For example, focusing on growth rather than maintenance allows the learner to make mistakes and

fail in the short term, while improving in the long term, unlike compensation theories for older adults, which suggest reducing activities after making mistakes (e.g., Brandtstädter & Greve, 1994, see also Schulz & Heckhausen, 1996).

Focusing on growth also may have an important impact on long-term functional independence: learning new real-world skills may be a requirement of maintaining functional independence to adapt in a dynamic environment (Nguyen et al., 2020), especially to technological advances (e.g., Charness & Boot, 2009). The ability to learn new skills to keep up with advances may be a better model of functional independence for currently healthy older adults who are able to complete basic daily tasks (e.g., bathing, grocery shopping), which currently are used to assess functionality. Given that the vast majority of our participants were at ceiling for their EPT scores (as well as for their IADL scores), we suggest that more sensitive, current, and adaptive measures be developed for functional independence in currently healthy older adults. Perhaps these measures can relate to willingness to learn new difficult skills, as well as experience doing so (e.g., Leanos, Coons, Rebok, Ozer, & Wu, 2019; Nguyen et al., 2020).

In general, having higher expectations for children has been known for decades to have important effects on cognitive and functional abilities, as well as self-efficacy and motivation (e.g., the Pygmalion effect, Rosenthal, 1994). We have proposed that our current expectations for being a functional, successful older adult are relatively low, compared with what we expect of emerging adults (Nguyen et al., 2020). The intervention from the present studies raises the expectations for being a successful older adult to include willingness to simultaneously learn many (and any) new difficult skills. Our intervention extends prior work on "staying active" (e.g., "use it or lose it," Hultsch, Hertzog, Small, & Dixon, 1999) and prior cognitive engagement interventions including learning only one skill at a time. Our results demonstrate the feasibility and potential of intense learning experiences in older adulthood akin to those encountered by younger populations. Perhaps learning new real-world skills is not merely one optional way of "staying active," but rather is an integral factor for cognitive growth and functional independence later in the life span. Future studies on this topic may find that such an approach may be effective at promoting cognitive growth over the long term in older adults to mitigate, delay, or even prevent general cognitive decline in late life.

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Conflict of Interest

None declared.

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